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estimating slash fuel loading for several lake states tree species

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NORTH CENTRAL FOREST EXPERIMENT STATION
FOREST SERVICE
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CONTENTS

Application 1

Documentation 6

Literature Cited 8

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THIS PAPER IS AN EXPERIMENT IN COMMUNICATION.

Realizing that the needs and interests of our two major "clients" — the scientist and the practitioner — are different, we have been concerned whether our publications have been in a form and style equally useful to both. So we have decided to try a new format for some of our Research Papers, one that might serve this dual purpose better. You are about to sample the first fruit of this effort.

The Paper is divided into two separate parts: Application and Documentation. The Application section is specifically intended for the man on the ground or in the mill who has a particular job to do or problem to solve. This section describes briefly the situation and the problem, and then goes immediately to the solution, emphasizing the how-to-do-it aspect. It is a complete story in itself; the busy manager need read no further.

The Documentation section describes the details of the research process. It is for the reader interested in laboratory and field procedures, tabulations, statistical analysis, and philosophical discussion. This section, too, is self-contained.

Our purpose is to separate the practical aspects of our research results from the strictly academic ones yet still make both available to all readers. If the practitioner wants to find out how we arrived at our recommendations, the details are in the Documentation section for him to examine. If the scientist has a practical bent, he can turn to the Application section and see the results in action.

It is for you to decide whether we have created a well-matched team or a two-headed monster. *We would like to have your opinion.*

ESTIMATING SLASH FUEL LOADING FOR SEVERAL LAKE STATES TREE SPECIES

Peter J. Roussopoulos and Von J. Johnson

APPLICATION

Fire behavior is greatly influenced by the amount of slash fuel on the ground. So the land manager concerned about fire control needs to know what kind and how much slash is present before he can devise a plan to prevent or control fire. Especially, he needs to know the sizes of slash material present, because the smaller pieces are most critical to fire behavior. Current methods of slash appraisal range from visual "guesstimates" to complex measurements and computations.

Presented here is a slash fuel survey method that we feel is easy to use and yet reasonably accurate. It involves simple field measurements used in conjunction with some alignment charts.

Field Procedure

Planar intersect sampling simply involves tallying by size and species all the stems, branches, and twigs ("particles") that cross above or below a number of sample lines. Any number and length of lines may be sampled, but of course the reliability of the sample increases as the total sample length increases. The finer the material the less length of line needed. If you have a relatively homogeneous slash area, 80 feet of sample line will give you accuracy to within about half a ton per acre for the finer material. If you want greater accuracy, you'll need a longer line. Or if you want comparable accuracy for larger material, you will need a longer line than that used for the "fines."

To avoid bias, the direction each sample line is run should be determined randomly. A table of random numbers or a simple "spin-the-bottle" game can be used to select the direction for each line.

Once you have established line length and direction, stretch a string or tape between two stakes or chaining pins and begin tallying (fig. 1). A prepared tally sheet simplifies the process (fig. 2). You can measure fine material (up to 1½ inches in diameter) with a go-no-go gage (fig. 3); estimate diameter of larger fuel ocularly, periodically checking with a diameter tape.

Figure 1. Branchwood particles intersected by the sample line are tallied by species and diameter class. In this photograph the sample is only one meter long, and is delineated in 25 centimeter segments by plumb-bobs suspended from a meterstick. A large number of these short samples must be taken to ensure reliable results.

Tally only those particles that actually cross the sample line. If a curved or angular particle crosses the line

Date_____ Observers_____

Area Identification_____

Sample Number_____ Direction of Line (Azimuth)_____

Branchwood Tally Form

Diameter class (Inches)	Line length	Jack pine	Red pine	Balsam fir	Spruce	Aspen	Birch	Other decid.	Other conifer
0-.25									
.26-.75									
.76-1.50									
2*									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									

* Range: 1.51-2.50, etc.

REMARKS:

Figure 2. Field tally sheet for planar intersect fuel sampling.

more than once it should be tallied for each crossing. Ignore particles that merely touch or parallel the line.

Office Procedure

Summarize the data for the entire sample area:

1. Total all the individual sample line lengths.

2. Total the number of particles intersecting the sample lines by diameter class and species.

3. Divide the total number of particle intersections for each species-diameter class combination by the total length of sample lines to get the average number of particle intersections per foot of sample line.

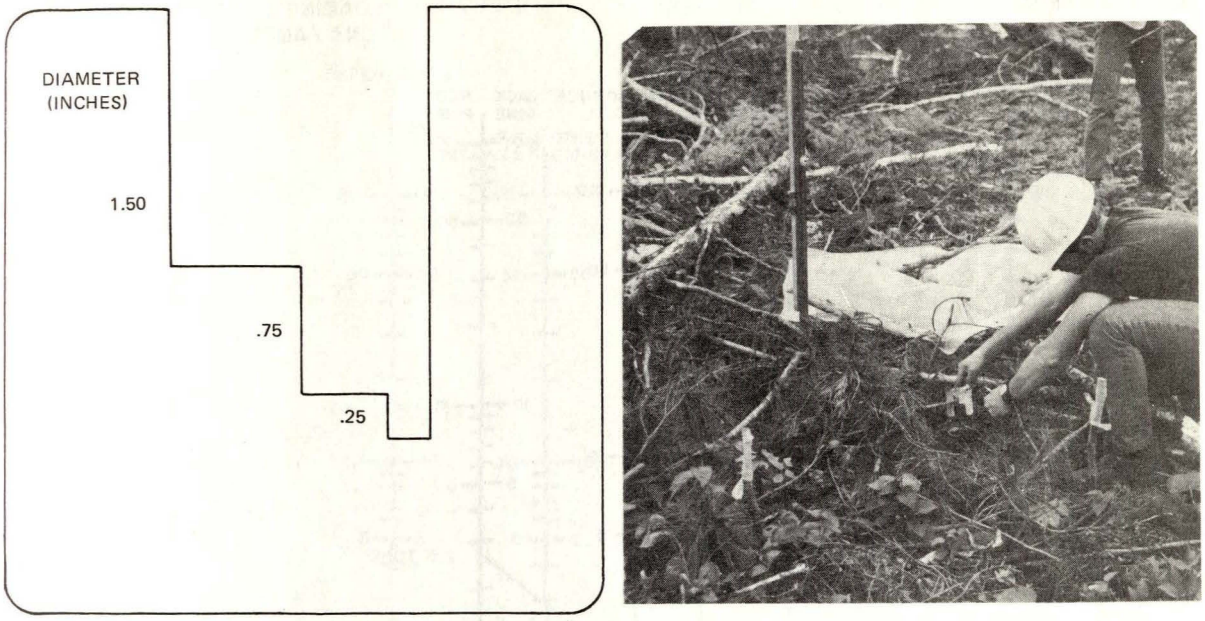

Figure 3. Sheet metal or plastic go-no-go gage may be used to determine fine fuel diameter classes.

Referring to the appropriate alignment chart (figs. 4 and 5):

1. On the far left scale find the point representing the number of intersections per foot of sample line for a certain species and diameter.

2. On the "Diameter Class" scale for the species in question, find the appropriate diameter.

3. Extend a straight line through these two points until it intersects the appropriate "Branchwood Fuel Weight" scale on the right.

4. Read the fuel weight in tons per acre at the intersecting point.

5. Repeat for all species-diameter combinations and add them all together to get total fuel weight per acre.

Example

Assume that ten 20-foot samples have been taken and that the numbers of ¼-¾-inch diameter jack pine particle intersections were 13, 54, 7, 22, 81, 42, 1, 132, 39, and 21. The total of these numbers (412) divided by the total sample line length (200 feet) gives an average of 2.06 intersections per foot of line. Locate this number on the left-hand scale of figure 4 and the ¼-¾-inch point on the jack pine Diameter Class scale and extend a line between these points to the jack pine fuel weight.

Estimating Foliage Weight

Foliage weight is directly related to the weight of the finest particles (¼ inch in diameter and smaller) and, for red pine, to the weight of particles as large as ¾ inch in diameter. Ratios of foliage weight to fine particle weight have been computed for three northern conifers — jack pine, red pine, and balsam fir — to facilitate calculating foliage weights for these species.

Three numbers are necessary to make the calculation:

1. Percent of foliage retained on the branches. (Obtained by ocular estimate.)

2. Ratio of foliage weight to branchwood weight. (For particles ¼ inch in diameter or less — jack pine - 1.6; red pine - 3.3; balsam fir - 0.9. Red pine was the only species having foliage on larger (¼-¾-inch) particles. Ratio for this size is 0.4.)

3. Branchwood fuel weight for the appropriate species and size. (Derived from alignment charts.) Multiply 1 by 2 by 3 and divide by 100 to get tons of foliage per acre. (For red pine this calculation must be done for both sizes of particles.)

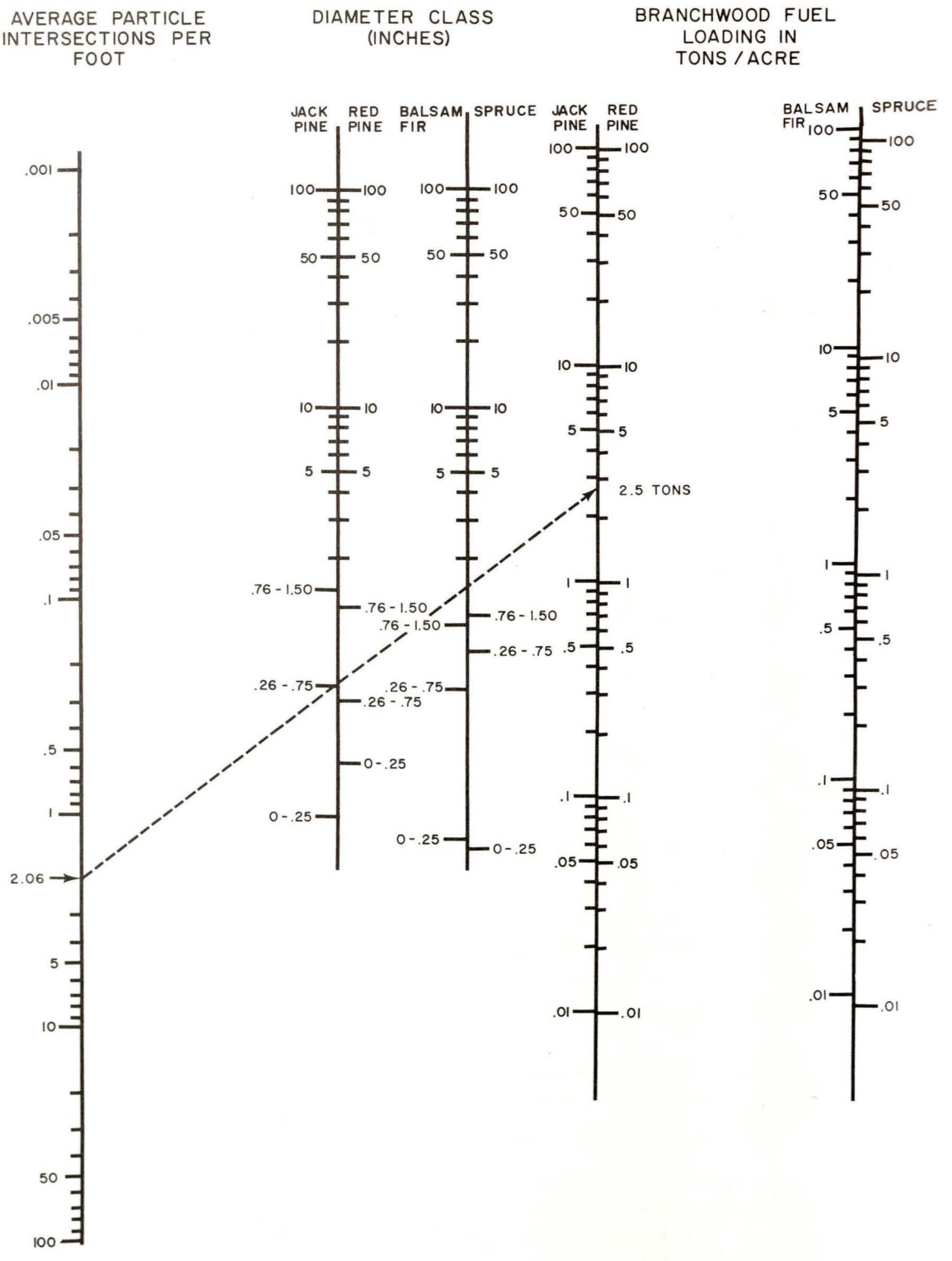

Figure 4. Nomograph determination of branchwood fuel loading for jack pine, red pine, balsam fir, and spruce.

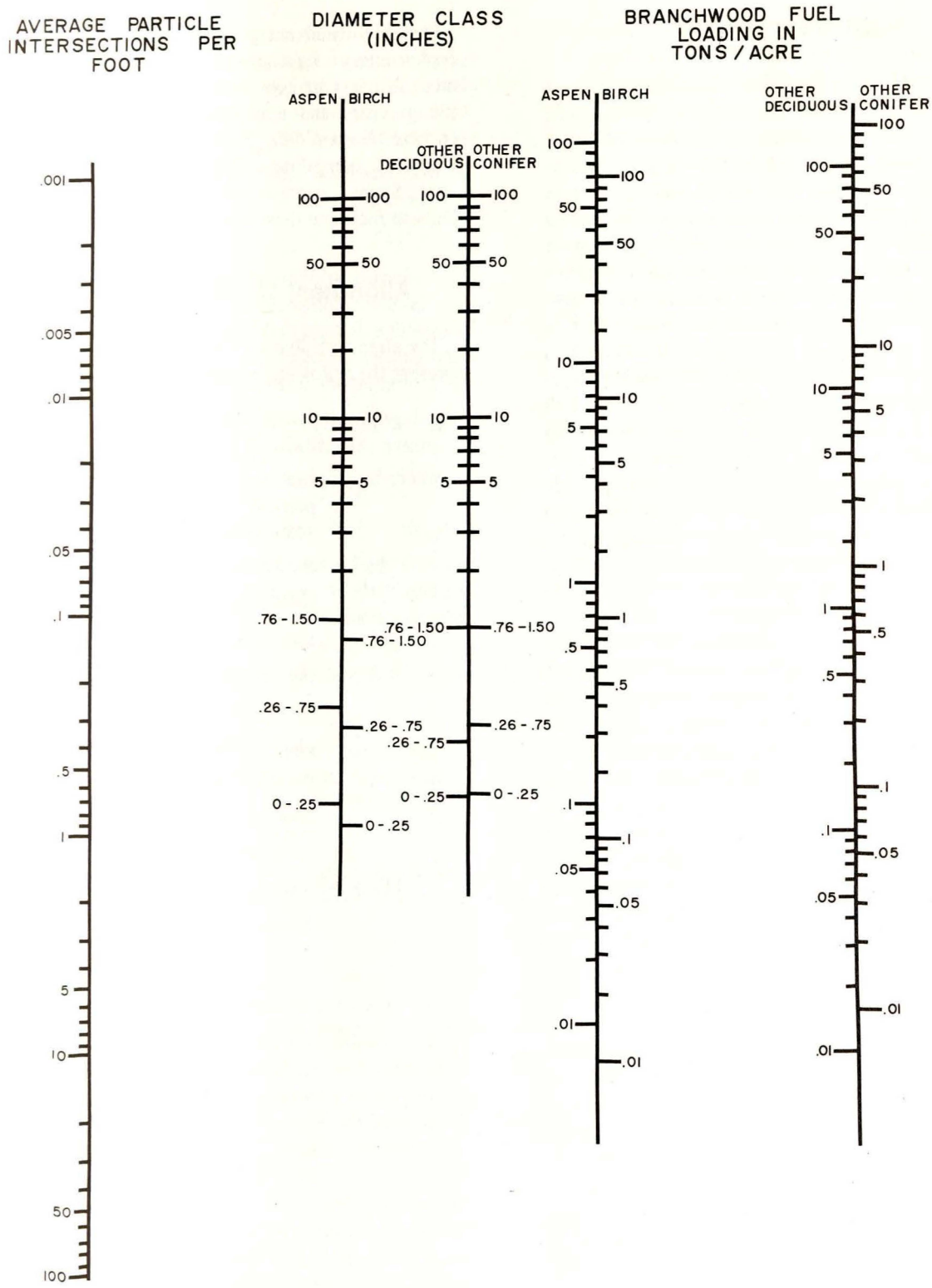

Figure 5. Nomograph determination of branchwood fuel loading for aspen, paper birch, other hardwoods, and other conifers.

DOCUMENTATION

Much of the recently published information on forest fire control, prescribed burning, and fuel management leans heavily toward quantified descriptions of forest fuels. Developments in fire control planning systems as well as the new National Fire Danger Rating System (Deeming *et al.* 1972) involve fuel descriptions of this nature. Loading of slash fuel (its weight per unit of ground area) is perhaps the measurement appearing most often in the literature. Usually it is expressed in tons per acre, but commonly in pounds per square foot as well. Because fire behavior is influenced greatly by fuel loading, sound decisions among alternative fuel management strategies require knowledge of the existing fuel load. Needed is a quick but reliable method of estimating slash fuel loading usable by field personnel at low cost. Availability of such a technique would not only provide a sound basis for fuel management decisions, but it also would allow "on-the-ground" decisionmakers to develop an intuitive "feel" for quantitative fuel descriptions.

Classic techniques for determining fuel loading involve weighing ovendry samples extracted from known plots and are expensive and time consuming. Crown weight tables have been helpful for slash weight estimates in conifer plantations, but in natural stands, where the fuel array includes many species, these are not totally satisfactory.

One promising alternative involves planar intersect sampling originally developed by Warren and Olsen (1964) to assess logging waste in *Pinus radiata* plantations in New Zealand. Detailed discussions of the theory, applications, and evaluations of this procedure have been reported by Bailey (1969, 1970), Beaufait,[1] Brown (1971), Dell and Ward (1971), and Van Wagner (1968). Since first applied to forest fuel sampling by Van Wagner (1968), the technique has been used successfully by many specialists to estimate fuel loading. With only a few simplifications it can be used by forest land managers as well. Advantages of this method include speed and simplicity in the field, minimal equipment requirements, and the relative ease with which fuel can be classified by species and size (important in view of the influence of the finer fuels on fire behavior).

One big disadvantage is the need for a bank of supplementary information on physical characteristics of the fuel components, such as particle specific gravities and diameter distributions within chosen size classes. We have overcome this objection locally by compiling the necessary data for several Lake States species and constructing alignment charts to facilitate their use.

Alignment Chart Development

The alignment charts were constructed to graphically represent the following equation.[2]

$$L_{ij} = 11.65\ N_{ij}\ S_{ij}\ \delta_{ij}$$

where L_{ij} = fuel loading in tons per acre of wood particles of the i^{th} species in the j^{th} size class.

N_{ij} = the number of particles intersected per foot of sample line in the ij^{th} species-size class category.

S_{ij} = the representative specific gravity of fuel particles in the ij^{th} species-size class category.

δ_{ij} = the representative squared diameter for fuel particles in the ij^{th} species-size class category.

11.65 = a constant of proportionality to express loading in tons per acre.

To satisfy the equation, the values of S_{ij} and δ_{ij} had to be determined for a number of species-size class combinations. The fieldwork for these determinations was conducted in a tornado blowdown area on the Virginia District of the Superior National Forest. The predominant species existing in this area were jack pine (*Pinus banksiana*), red pine (*Pinus resinosa*), balsam fir (*Abies balsamea*), spruce (*Picea*), aspen (*Populus*), and white birch (*Betula papyrifera*). The "other deciduous" and "other conifer" categories were created to represent less frequently encountered species.

Representative squared diameters (δ_{ij}) for the three smallest size classes were determined by measuring to

[1] *Beaufait, W. R. Prescribed fire cooperative study. Study Plan N. 2102-12 on file at Int. For. & Range Exp. Stn., North. For. Fire Lab., USDA For. Serv., Missoula, Mont. 1967.*

[2] *A modification of that given by Van Wagner (1968).*

the nearest 0.01 inch, the diameters of all particles of these sizes intersecting a number of planar intersect samples. Each measurement was squared and the squared diameters averaged for each species-size class combination to obtain the values of δ_{ij} (table 1). The data for ¾-1-½-inch "other conifers" were insufficient to determine δ, so a value of 1.25 in.^{2} was subjectively assigned to this class.

Because the frequency distribution of particle diameters resembles a highly skewed gamma curve, it is assumed that diameters within the larger size classes (2 inches and larger) are distributed with nearly equal probability, and that δ_{ij} is equivalent to the square of the class midpoint. Although this assumption introduces a bias, it is considered negligible within such narrow (1-inch) size classes.

Evidence suggests that particle specific gravities (S_{ij}) become greater in smaller diameter particles.[3] This can be attributed to higher concentrations of pitch and extractives, and the larger proportion of volume occupied by bark in smaller particles. However, specific gravities were assumed to be relatively constant in the larger diameter classes.

For these classes (2 inches and larger) specific gravities given in the *Wood Handbook* (U.S. Department of Agriculture 1955) were used. For the smaller classes values were determined empirically. Air-dry volumes were measured by a mercury displacement technique and weights were found after ovendrying 24 hours at 105° C. (table 2). Data were insufficient for estimates of ¾-1-½-inch spruce and "other deciduous" and all "other conifer" specific gravities. The *Wood Handbook* value 0.40 was used for the spruce and a value of 0.50 was assigned to the "other deciduous." As a compromise between *Wood Handbook* values for eastern white pine (*Pinus strobus*) and northern white-cedar (*Thuja occidentalis*), "other conifer" species were assigned a specific gravity of 0.32 for all classes.

Using equation 1, then, the values given in tables 1 and 2 were built into the logarithmic scales of the alignment charts (figs. 4 and 5).

Estimating Foliage Loading

Good loading estimates for foliage are slightly more elusive than for branchwood fuels. It is not practical to count foliage intersections in the planar intersect sample, and large-scale extractive sampling of foliage would be too time consuming and expensive. Brown (1970) estimated foliage loading in spruce-fir logging slash in western Montana by determining the ratio of foliage weight to the weight of ¼-inch or less branchwood. This was done by stripping the foliage from sample branchwood, weighing the ovendried needle and branchwood components, and dividing the former by the latter. The product of this foliage weight ratio and the ¼-inch branchwood loading estimate, furnished by the planar intersect sample, is the estimate of foliage loading.

[3] *Personal communication with James K. Brown, Northern Forest Fire Laboratory, dated October 2, 1970.*

Table 1. — *Representative squared diameters (δ_{ij}) for small size classes (Square inches)*

Species	Size class (j) (inches)					
	0-.25		.26-.75		.76-1.50	
	Mean	Standard error	Mean	Standard error	Mean	Standard error
Jack pine	0.012	0.001	0.230	0.012	1.197	0.056
Red pine	.034	.003	.150	.031	1.309	.044
Balsam fir	.005	.001	.225	.019	.822	.010
Spruce	.005	.002	.304	.067	1.108	.155
Aspen	.022	.002	.211	.019	1.165	.184
Birch	.016	.003	.160	.025	1.237	.397
Other deciduous	.028	.004	.100	.013	1.254	.034
Other conifer	.041	.017	.169	.018	***	***

*** Insufficient data.

Table 2. — *Particle specific gravities (S_{ij}) for small size classes*

Species	Size class (inches)					
	0-.25		.26-.75		.76-1.50	
	Mean	Standard error	Mean	Standard error	Mean	Standard error
Jack pine	0.554	0.025	0.510	0.023	0.441	0.042
Red pine	.607	.017	.548	.020	.460	.008
Balsam fir	.695	.029	.404	.050	.408	.006
Spruce	.601	.029	.644	.042	***	***
Aspen	.591	.034	.444	.036	.490	.017
Birch	.685	.021	.545	.020	.484	.008
Other deciduous	.654	.034	.576	.014	***	***
Other conifer	***	***	***	***	***	***

*** Insufficient data.

If the time and equipment are available, this procedure provides good foliage loading estimates. Fifteen or twenty sample branches for each species should provide reasonably reliable ratio estimates.

When the time or equipment is not at hand and a foliage loading estimate is desired for jack pine, red pine, or balsam fir, refer to the alternative procedure described on page 3. Ratios of foliage weight to ¼-inch or less branchwood weight were determined for these species. The samples were collected near Virginia, Minnesota, from branches retaining all of their foliage. No needle fall had occurred prior to sampling. To apply these ratios, a subjective estimate of the proportion of needles retained on the branches is required for each coniferous species in the sample area. This may be expressed as the percent of the total possible needles (assuming no needle fall) remaining on the branches.

Summary

The current trend toward increasingly sophisticated forest management planning systems indicates a need for better methods of obtaining required inputs to these systems. If fuel management is to be practiced intelligently, managers must be able to assess fuel hazard in quantitative terms. A set of alignment charts has been presented to aid in assessing slash fuel loading, one component of fuel hazard. Use of planar intersect sampling with the associated fuel loading alignment charts provides a rapid and fairly reliable method of estimating slash fuel weights by species and diameter class.

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